2 (MN)

CR - 130770

THE PENNSYLVANIA STATE UNIVERSITY
220 ELECTRICAL ENGINEERING WEST BUILDING
UNIVERSITY PARK, PENNSYLVANIA 16802

Space Science and Engineering Laboratory
Office for Remote Sensing of Earth Resources
Telephone: 814-865-9753

Co-directors:
G. J. McMurtry
G. W. Petersen

ERTS Program Manager
Code ER, NASA Headquarters
Washington, D.C.

March 2, 1973

Dear Sir:

In accordance with Article II of contract number NAS5-23133 covering the proposal, "Interdisciplinary Applications and Interpretations of ERTS Data within the Susquehanna River Basin; Resource Inventory, Land Use and Pollution", dated April 1971 (NASA Control Nos. Y-39009-212 and SR082), this letter is the Type I Progress Report covering the period December 1, 1972 to January 31, 1973.

1. Accomplishments

The major accomplishments during the period of this report can be summarized as follows:

a. Extensive processing of several ERTS frames was initiated and is continuing. The processing included digital processing, photointerpretation, and a combination of both.

(1). In digital processing, CCT's were proposed according to the standard ORSER plan by first subsetting the original tapes into smaller working areas. Intensity and uniformity computer maps were produced along with basic statistics in order to select training areas and areas for further investigation. Classification programs were then applied and maps were produced which indicate various categories of water, vegetation, etc. New classification programs were developed, tested, and proven useful. These programs were based on canonical and cluster analysis. Other programs were developed including merging and change detection programs used to combine data from two frames of the same scene (different passes of ERTS) and then to compare the data and observe

(E73-10327) INTERDISCIPLINARY APPLICATIONS AND INTERPRETATIONS OF ERTS DATA WITHIN THE SUSQUEHANNA RIVER BASIN; RESOURCES INVENTORY, LAND (Pennsylvania State Univ.) 31 p HC $3.75 CSCL 08H

N73-18358

G3/13

Unclas
00327

31

any changes that may have occurred during the intervening time between passes. Also during this period, the Computation Center at Penn State changed its principal computer from an IBM 360/67 to an IBM 370/165. All programs were used on the new system without conversion and a minimum of down-time was experienced.

(2) ERTS imagery was analyzed using light tables and stereoscopes, both for its own information content and in conjunction with the above digital analysis. The digital data, of course, gave much better resolution and greater detail of information.

(3) Aircraft imagery was found to be an essential part of the investigation. Data obtained from U-2 and C130 underflights was used extensively as a form of ground truth by projecting aircraft imagery, for example, on to computer maps of the same scale and verifying correctly classified outputs. In some cases, the computer maps were found to be useful aids in locating very small areas of a particular type of object on the aircraft imagery.

b. As a not unexpected result of preliminary ERTS-I work, ORSER strongly feels that a hybrid approach is necessary. Computer differentiation of areas from scanner data is far superior to that done by the human eye, but the photointerpreter is essential, as an integral part of the data processing, for providing identification of features exhibited on computer output. Consequently, a detailed and refined procedure for processing and interpreting ERTS data was developed by ORSER during this period. This procedure is discussed in section 2.2.2 of Appendix A to this report. Appendix A describes the overall ORSER processing system, with section 2.2.1 briefly describing the CCT tape processing procedure while section 2.2.2 describes the hybrid approach utilizing both automatic data processing and photointerpretive techniques. Appendix A is copied directly from the ORSER proposal for ERTS-B and, in the interest of time, has not been retyped or edited.

c. Analytical results obtained during this period include:
(1) indentification and mapping of coal refuse banks and other targets in the anthracite region;
(2) mapping of strip mines and associated vegetation;
(3) regional geological mapping;
(4) mapping of agricultural land use; and

(5) classification, mapping, and comparison of two temporally different ERTS images of the same geographical area.

These five results are considered significant and are discussed in part 2 of this letter below. Other results obtained during this period were primarily developments of interpretation techniques and three of these are now discussed.

(1) Classification of ERTS -I MSS Data by Canonical Analysis
The objective of canonical analysis as applied to the classification of MSS data is to obtain the maximum separability among a number of categories. For each category the spectral signature (i.e., the mean vector) and the covariance matrix are computer based on a number of observations which belong to the category. Based on this, an orthogonal transformation is derived which maximizes category separability in as few axes as possible. Each unknown observation can be classified into one of the categories on the basis of the euclidean distance between the transformed unknown vector and each of the transformed category mean vectors with certain constraints. Alternatively, the classification can be done by a table look-up technique for increased computational speed. A computer classification program on this concept has been written and tested, and is now an operational program in the ORSER system.

(2) Hybrid Approach to Processing of ERTS Data Using MSS Tapes and U-2 Photography
An urban area in central Pennsylvania and the surrounding locality were first investigated separately by photointerpretation of ERTS-I imagery and by computer processing of MSS tapes. Each of these independent approachs had shortcomings. Next the photointerpretation and processing were coordinated. The results of the cooperative effort of photointerpreters and computer processing analysts were much improved over independent efforts. It was found that single frames of U-2 photography could be projected onto printer output maps with little recognizable distortion in areas 10 to 25 cm square. In this way targets could be identified as training areas for signature identification by computer processing. In addition, at any stage of category mapping, the level of success in correct classification could be assessed by this method. Between 10 and 20 signatures and identifiable targets have been found from ERTS-I data ranging from metropolitan areas to open land.

(3) MSS Data Evaluation and Detection of a Data Anomaly

It was first noticed in processing MSS data for scene 1045-15240 that every sixth scan line was substantially different from the rest. The problem was found to be with channel six. For every sixth line, channel six data were inconsistent with the channel six data for other lines. It should be noted that in the ERTS-I MSS configuration, six sensors operate in each channel simultaneously, each sensing one of the six scan lines. The specific cause of the trouble is unknown, but the computer analysis of such data was examined for other scenes and the same data anomaly was discovered. In one scene, the data discrepancy was subtle enough so that it could easily remain undetected by the user in the computer mapping even though the classification and mapping were substantially biased. Corrective measures and the consequences of using uncorrected data in computer analysis and processing are being investigated. This problem has been discussed with Mr. W.L. Alford, NASA/GSFC, and some computer output containing this anomaly has been forwarded to him.

d. During the period of this report the activities of ORSER were discussed with various state agencies of the Commonwealth of Pennsylvania. The potential use of ERTS and aircraft remote sensing data was illustrated and considerable interest was generated. Specific agencies contacted include the Pa. Department of Environmental Resources, Pennsylvania Department of Transportation, Pennsylvania Geological Survey, and the Pennsylvania Department of Agriculture.

e. Underflights were flown by NASA aircraft during this period as follows:

Date	Platform	Sensors
1/3,10/73	C-54 (Wallops)	T-11(Color IR) I^2S(Multiband)
1/12,13/73	C-130(MSC)	RC-8(Color;Color IR) Hasselblad(Multiband) MSS
1/12/73	U-2 (Ames)	Vinten(Multiband) MSS

2. Significant Results

Significant results obtained during the period of this report are summarized below. A more complete discussion of these results is being prepared for presentation at the ERTS-I Symposium on March 5-9, 1973.

a. Identification and Mapping of Coal Refuse Banks and Other Targets in the Anthracite Region

An area in central eastern Pennsylvania, which includes parts of the Eastern Middle Coal Field and the Southern Coal Field of the Anthracite Region, was investigated using ERTS-I MSS data for the frame 1080-15183 collected October 11, 1972. The objective was to determine how well accumulations of coal refuse and associated targets could be identified and mapped by computer analysis and processing.

Three major kinds of coal refuse targets exist: culm piles, silt piles, and silt sedimentation basins. These targets are predominantly black to the eye. They were found to have spectral signatures which had relative reflectances in channels four through seven in the order of 4, 5, 6, 7, with channel seven having slightly higher reflectance than water targets.

Correlation of the placement of the coal refuse targets with an existing map of their locations was made. At this time no underflight photography was at hand with which to judge the mapping success. Correlation was made with 1:24,000 scale USGS maps dated 1947 and 1948.

Other targets of interest in the area which could be identified by signatures were an upland swamp, water impoundments, communities, bare land related to strip mining for coal, and vegetation. Traces could be recognized for two-lane and wider highways, multiple-track railway right-of-ways, and a gas line right-of-way.

b. Mapping of Strip Mine Areas in Pennsylvania

Digital processing of ERTS-I MSS data from the frame 1045-15240 of September 6, 1972, for areas around the west branch of the Susquehanna River permits identification of stripped areas including ones that are not discernible by visual analysis of ERTS imagery. Underflight data and ground-based observations are used for ground-truth and as a basis for designing more refined operators to make sub-classifications of stripped areas, particularly with regard to manifestations of acid mine drainage; because of associated diagnostic effects on vegetation, seasonal changes in classification criteria are being documented as repeated, cloud-free ERTS-I coverage of the same area becomes available. Preliminary results indicate that ERTS data can be used to moniter not only the total extent of stripping in given areas but also the effectiveness of reclamation and pollution abatement procedures.

In this investigation, U-2 photography was enlarged 4 times and the computer classification outputs were produced as line maps at the same scale as the enlarged photography. These two forms of data were then projected as an overlay and compared. In addition, the U-2 photographs were viewed in stereo to check classification results.

Specific findings include:

(1). detection of sediment ponds in the strip mine area. These did not appear in the U-2 photos becuase they were taken earlier in the year when the ponds were dried up. Immediately prior to the overpass of ERTS it had rained for five days and over 2 inches of precipitation was recorded in the area. The signature of the pond water was sufficiently close to that of the Susquehanna River water that the latter was used as training data for preliminary detection of sediment ponds.

(2). detection of spoils in a river valley. The valley was steep and narrow and the spoils were apparently pushed over the side of a mountain. These spoils were first detected on the computer map output and later verified on the U-2 photography. They were not easily detectable on the photography and not visible at all on ERTS imagery.

(3). detection of vegetation associated with strip mining operations. The vegetation detected does not appear to be reclamation, but may be native vegetation affected by stripping operations or geologic influences. This particular result needs further ground truth for proper and complete identification.

(4). detection of a bridge across the Susquehanna River near Keewaydin, Pennsylvania.

c. Regional Geologic Mapping

Combined visual and digital techniques of analyzing ERTS-I data for geologic information have been tried on selected areas in Pennsylvania. ERTS data used for the early part of this investigation has been primarily the imagery from frames 1045-15243 and 1080-15185 of September 6 and October 11, 1972, respectively. Correlations are made via the underflight interpretation of the surficial geology and the "ground-based" bedrock geology maps. The criteria used in mapping like areas (similarity invisual tone, spatial patterns, or texture) are classified according to whether they represent a direct or indirect manifestation of the bedrock conditions. In forested areas such as Pennsylvania a knowledge of the indirect indicators is important for geologic interpretations even though their relationship to the bedrock conditions may not be understood.

Based on favorable preliminary results(visual) the following features have been selected for more detailed analysis: (1) the Triassic basin of Eastern Pennsylvania, (2) the diabase sill flows and dikes of Eastern Pennsylvania, (3) the anthracite "basin" around Scranton, (4) the Precambrian inliers of the "Reading prong", (5) the Philadelphia areas, and (6) the transgressive linear feature through Mount Union to Tyrone.

The physiographic provinces in Pennsylvania show up well, particularly the folded Appalachians in bands 7 and 5, and while the MSS images afford an excellent base for regional mapping, little new "geology" is expected to be added to the existing geologic maps. However, the remarkable correlation to "ground truth" geological data demonstrates the feasibility of locating geological boundaries in unmapped areas. As an example, the combined use of time, boundary shape, vegetal cover, and characteristic spectral response has been used in mapping diabase sills and flows in Southeastern Pennsylvania. Some of the associated ore deposits are aligned along a possible linear zone. Several lineaments that transgress the regional structural grain and also some of the physiographic provinces have been discovered from visual examination of the MSS images. The origin of these features and their possible association with underground water supplies and mineral deposits is currently being investigated using underflight and various forms of ground-truth data. Lineament mapping from digital data is cumbersome because of the length of lineaments and unreliable because of their variation in expression along strike (e.g. between ridges and valleys) and the difficulty of distinguishing anthropomorphic effects (roads, field boundaries, etc). Although area selection and lineament mapping are based on a visual analysis of the MSS images (and are biased to some extent by the observer's ground-based knowledge of the area), the most powerful analytical technique for mapping boundaries is the digital processing using all or combinations of MSS channels.

d. Mapping of Agricultural Land Use

A study area was selected in Lancaster and Lebanon Counties, two of the major agricultural counties in Pennsylvania. This area was delineated on positive transparencies of MSS data collected on October 11, 1972 (1080-15185). Channel seven was used to delineate general land forms, drainage patterns, water, and urban areas. Channel five was used to delineate highway networks. These identificable features were useful aids for locating areas on the computer output.

Computer generated brightness maps were used to delineate broad land use categories, such as forest land, agricultural land, urban areas and water. Attempts are being made to produce a type of soil association map of bare soil areas using computer classification techniques. These digital maps have a scale of approximately 1:24,000, thereby allowing direct comparison with U.S.G.S. 7.5 minute quadrangle sheets. Comparisons with soil association maps have also been made through projection techniques.

Data collected by the University of Michigan aircraft and the NASA NC-130B aircraft were used as a form of ground truth for the delineation of land use patterns.

e. Use of the Temporal Dimension in Classification and Mapping

ERTS-I MSS data from two frames of the same central Pennsylvania area were brought into registration by translation and then merged, The two frames were obtained 71 days apart by ERTS and are from adjacent ground tracks as frequent cloud cover in Pennsylvania made it impossible to choose two from the same track. The frames under consideration are 1009-15241 and 1080-15185 of August 1 and October 11, 1972, respectively.

Targets selected to be mapped included river water, railroad yards, creeks, urban areas, industrial areas, and vegetation. Signatures were obtained for these targets by selecting locally uniform training areas and computing the mean signatures. To compensate for possible misregistration,areas were chosen well within larger uniform boundaries. Cluster analyses were used to obtain signatures for targets, such as a creek, for which no sufficiently large uniform areas could be defined. The application of canonical analysis was also investigated using the merged data.

Equivalent training areas were chosen from each of the original scenes and from the merged data. Classification maps were produced for each, and a comparison study was made of all three maps. Greater mapping success was obtained using the merged data. Because of temporal effects, the separability among some targets was increased thus improving classification success. The contribution of each of the four channels in each set toward the separability of the major targets was also observed and is undergoing continuing investigation.

Experiments with merged data indicates that blocks of considerable size may be brought sufficiently into registration by translation to enable further analysis. Considerable changes in signatures for various targets were observed for two frames.

3. Standing Order Change

A request for a change in the standing order was submitted on December 19, 1972.

4. Data Request Form

An extensive set of retrospective orders was submitted on December 27, 1972.

5. Other Activities

Other related activities of ORSER during the period of this report are indicated below.

a. Using Penn State University funds, new equipment was ordered including brackets for a light table and a Bausch and Lomb Zoom Transferscope. The latter instrument permits the projection of opaque or transparent images onto a plain surface or another image, with the capability of magnification in any direction, and selectively in a single direction, from 1X to 7X. This instrument will make it possible to project a photograph onto a computer generated map with adjustment of the line and element distortion inherent in the computer output.

b. The processing and classification programs of ORSER were provided to Mr. Paul D. Hopkins of the U.S. Department of Agriculture Statistical Reporting Service for the purposes of testing their ease of application by non-university users and determining the ease or difficulty with which they might be implemented on other computers. Preliminary indications are that the transfer and application of the programs can be performed with minimal difficulties.

c. An ERTS-B proposal was prepared in close cooperation with state agencies and with applications to state problems. Although experience with ERTS-I data was limited prior to the writing of this proposal, it was sufficient to assist ORSER and the state agencies in determining those problems which could most effectively be attacked using ERTS and supporting aircraft data.

d. ORSER personnel participated in local radio and TV programs in which the ERTS system was discussed. Newspaper articles were also written about ERTS and the ORSER participation. Although these programs and articles dealt with ERTS in only the most general terms, considerable public and professional interest was aroused. ORSER entertained many visitors and answered many inquiries of general nature, and was forced to decline some requests for specific results which had not yet been released in compliance with the provisions of Article IX of the contract.

6. Plans

It is anticipated that the analysis of ERTS data will be continued with emphasis on tasks in the areas of geology, agriculture, strip mines, land use, and water resources. Continued development of interpretation techniques, particularly those related to the temporal aspects, can be expected.

Sincerely,

George J. McMurtry

George J. McMurtry
GSFC Ident.No. UN 159

cc: P. Ebaugh
E. Szajna (Technical Monitor)
H. Mathews (Scientific Monitor)
ERTS Contracting Officer
ERTS Technical Officer

APPENDIX A

ORSER

PROCESSING SYSTEM AND PROCEDURES

2.2 APPROACH

Through experience with ERTS-1 and aircraft remotely sensed multispectral data, ORSER has developed an operational system for processing of both imagery and computer compatible tapes. The ORSER system for processing MSS digital (See Borden, F. Y., Remote Sensing of Earth Resources, vol. 1, Tenn. Space Institute, University of Tenn., 1972) was developed for use by a wide variety of researchers in remote sensing at The Pennsylvania State University. These potential users represent many disciplines and have a wide range of experience and skill in computer usage.

The main computer is the IBM S/370 Model 165 which is dedicated to general university research and educational uses as well as to similar nonuniversity uses. Users may have access to the computer in any of three ways: (1) central and remote high speed dispatch points operated by the Computation Center, (2) slow speed Remote Job Entry (RJE) terminals using IBM 2741 or similar terminals supported by the user or by the Computation Center, and (3) intermediate speed remote batch terminals such as the IBM 2780 supported by the user or the Computation Center. The processing system for MSS data was developed to use any of these entry points. The RJE terminals are used for most developmental work. Bulk output for final runs is directed from an RJE terminal to any of the high speed terminal sites. The MSS data processing programs exist in library files in the computer so no program card decks need to be input. Files for building control information or storing output are available to the user. MSS data is input from magnetic tapes. The Computation Center manages the data tapes as well as user-owned work tapes. Nonuniversity users as well as university users may join the system, either locally or via long distance telephone lines.

A standard digital tape format was designed within which all known MSS sources could conveniently be placed. A tape file contains data for only one flight line. More than one file per tape is allowed as well as a continuation of a file to another tape. Within the file four kinds of records exist: (1) identification records, (2) table of contents record, (3) MSS response records, and (4) history records. Each MSS response record consists of a complete scan line. Each scan line is numbered and scan lines are always in ascending order in a file. The table of contents record indicates the actual contents of the file. A working file will usually contain only a small part or parts of the whole data set for a flight line. The table of contents is particularly useful in such cases in avoiding costly searching for data which is not present in the file.

The system is couched in a multivariate framework. Although it is understood that some operations do not require this statistical basis, this approach is, overall, most appropriate. Each observation, identifiable by scan line and element number, consists of a vector with as many elements as there are channels. At present, each vector is composed of just MSS response values; however, it is anticipated that the vectors will be augmented by other nonscanner data such as topographic data or transformed scanner data.

The system is not in a conversational mode where the user and the system dynamically interact during processing. Each program accepts input control specifications, processes the MSS data according to the specifications and outputs the results. The user prepares the control specifications for each program.

Although the system is non-conversational, the preparation of the control specifications by the user who is operating from an RJE terminal is conversational. For non-RJE operation, control specifications are made and entered into the system by punched cards. In RJE use, all control specifications are identical in format to the corresponding punched cards.

In this section, descriptions are provided of the general approach to be taken by ORSER in the processing of ERTS-B digital tapes, combined photointerpretive and automatic data processing of ERTS-B imagery, and the coordination of the ERTS-B investigation with state agencies. The programs discussed below are all operational and are documented at the users level. Many other programs are used, but the discussion below illustrates the general approach.

2.2.1 PROCESSING OF ERTS MSS TAPES

The approach used in the processing of ERTS MSS and other digital MSS tapes is defined in this subsection. During the ERTS-1 investigation, the system has been run for production a number of times and has been extended to meet the needs of various subprojects. The system was designed to be easily augmented and this has been done by the addition of a number of supervised and unsupervised analysis and classification algorithms.

First the general procedure to be employed for a previously unstudied area or type of target will be presented. The procedure to be employed for areas or targets which have been previously investigated is somewhat different and simpler.

The first step is to select the particular targets and areas of interest in Pennsylvania, primarily using maps. Following this the catalogues of imagery and digital tapes described in Appendices C and D are employed to determine what data is available and of what quality. Tapes corresponding to the selected ERTS scenes are chosen and the areas of useful data are specified in order to obtain these as subsets on work tapes. Subsets are produced on separate tapes using the SUBSET program. These subsets are prepared to gain rapid processing and short turn around time. This step is likely to have already been done in the process of cataloguing and storing ERTS tapes by ORSER, in which case the appropriate library subset tapes would be selected.

A run is then made with the NMAP program to show the general patterns of the data. This program was written to use all channels or any subset of channels and map element brightness based on these channels. The measure of brightness was taken as the norm of each multivariate vector. The norm is then converted to the percentage of the maximum possible value. This is then translated to the mapping symbol for the percentage range within which it falls. The process is done for every element in every scan line in the data blocks specified by the user. Output from the NMAP program consists of a brightness map.

The UMAP program is then run to map areas of local spectral uniformity. Each element is compared with each of its near neighbors using the euclidean distance between spectral signatures as the measure of similarity or dissimilarity. For each element, if the largest distance is smaller than a value specified by the user, then the symbol for uniformity is assigned to the element. The map which is produced shows the pattern of uniformity from which the user can designate corrdinates for training areas for the targets of interest. The program can be used separately or simultaneously for the mapping of contrasts.

The signatures and associated statistics are next obtained for the training areas by the use of the STATS program which computes the multivariate statistics for one or more training areas. The user designates a training area and the program computes the statistics for all of the data which fall within the boundaries. The mean and standard deviation vectors are found. The correlation and variance-covariance matrices are computed as well as the eigenvalues and eigenvectors of these matrices. Frequency histograms for selected channels can also be computed.

3

When it is decided that most of the targets have been identified by training areas, then a classification run is made using the classifier or classifiers deemed most appropriate for the mix of targets under consideration. A variety of classification programs are available including parametric and non-parametric classifiers with either linear or quadratic discriminant functions. Preprocessing before classification is also possible using programs for normalization, principal components, etc. The output of these programs is in the form of a character of digital map, with each category of classification being represented by a unique symbol.

Finally, the LMAP program is available for producing line maps from the character map. This produces an output on the CalComp plotter. Character or digital maps are useful primarily as working maps for the user in his analysis of MSS data. They are inherently distorted in the length to width relation because of the fixed number of lines and characters per inch of line printers. The LMAP program is intended for the production of finished copy maps. There are three main advantages for line maps as compared to character maps. First, orthographic maps to a selected scale can be made. Second, photographic overlays can be prepared and this is quite important in the comparison of the classification results with the corresponding aerial photograph as well as in checking the map against ground truth using the map and the aerial photograph together. The third advantage is that legible maps for publication purposes can be prepared.

An example of the use of the programs described above is given in Figures 6-14. The MSS data used for this digital analysis sequence came from ERTS-1 passes on two different dates, but the scenes are in the same local geographic area on the west bank of the Susquehanna River opposite Harrisburg, Pennsylvania. Figures 6 and 7 are from the ERTS-1 pass on October 11, 1972. As seen by the scan line and element numbers on the side and top of these figures, respectively, the NMAP and UMAP shown here are not of the same area. The blank areas of low brightness of the NMAP in Figure 6 generally follow the Conodoquinet Creek, while the high local uniformity (U) region diagonally across the upper right half on the UMAP of Figure 7 are of the Susquehanna River. Basic statistics and histograms for the data of Figure 7 are shown as output from the STATS program in Figures 8 and 9.

Figure 10 is the output of one of the classification programs, DCLASS, which classifies according to a minimum Euclidean distance algorithm. The legend shows a partial

BRIGHTNESS MAP (NMAP) OF
CONODOGUINET CREEK AREA

```
   700| 705| 710| 715| 720| 725| 730| 735| 740| 745| 750|
      |    |    |    |    |    |    |    |    |    |    |
1311 |X----XXXXXXXXXXXXXXXXXXXXXX---   --------     XXXXX|
1312 |X--XXXXXXXXXXXXXXXXXXXXXXXX- -      -----    XXXXXX|
1313 |X--XXXXXXXXXXXXXXXXXXXX-XX   XXXXXX         XXXXXXX|
1314 |XX--XXXXXXXXX---XXXXXX-XXX  XXXXXXXXXX     XXXXXXX-|
1315 |XXX---XXXXXXX----XXXXX--X   XXXXXXXXXXXXXXXXXXXXXXX|
1316 |XXXX--XXXXX  X-   -X----X   XXXXXXXXXXXXXXXXXXXXXXX|
1317 |XXXX--XXX-     -   ----XX   XXXX--XXXXXXXXXXXXXXXXX|
1318 |XX-----X-   -----   -XXXXX   X-----XXXXXXXXXXXXXXXX|
1319 |XX--XX--    ----XX   XXXXX   ------XXXXXXXXXXXXXXXX|
1320 |XXX--XXX-    ---XXX  XXXXXX   ---XX-XXXXXXXXXXXXXXX|
1321 |XXXX--XXX    --XXXXX  XXXXXX   XXX----XXXXXXXXXXXXX|
1322 |XXXX---XX-   -XXXXXXX  XXXXXX   -------XXXXXXXXXXXX|
1323 |XXXX------   -XXXXXXX   XXXXXX  ----XXXXXXXXXXXXXXX|
1324 |XXXX-------   XXXXXXXX   XXXXX  ---XXXXXXXXXXXXXXXX|
1325 |---XX--XXXX   -XXXXXXX   XXXXX   --X--XXXXXXXXXXXXX|
1326 | -----XXXXXX  ---XXXXXX   XXXXX   ---XXXXXXXXXXXXX |
1327 | -----XXXXXXX   --XXXXXX   XXXXXX   --XXXXXXXXXXXXX|
1328 |  -----XXXXXXX   --XXXXXX   XXXXXX   -----XXXXXXXXX|
1329 |   ----XXXXXXXX  --XXXXXXX   XXXXXXX    --XXXXXXXXX|
1330 |X   ----XXXXXXXX  --XXXXXX    XXXXXXXX      XXXXXXX|
1331 |XX  ---XXXXXXXXX   --XXXXXX   XXXXXXXXXXXX   -XXXXX|
1332 |XX-    -XXXXXXXXX  --XXXXXXX   XXXXXXXXXXXX    XXXX|
1333 |----    XXXXXXXXXXX  -XXXXXXX    XXXXXXXXXXXX   XXX|
1334 |-----   -XXXXXXXXXXX  -XXXXXXX    XXXXXXXXXXX   XXX|
1335 |--X--   -XXXXXXXXXXX   -XXXXXXX    XXXXXXXXXX   XXX|
1336 |-XXXX-   XXXXXXXXXXXX   XXXXXXX-    XXXXXXXXX   XXX|
1337 |XXXXX-    XXXXXXXXXXX   -XXXXXX--    XXXXXXX   XXXX|
1338 |XXX----    XXXXXXXXXX    XX------             XXXXX|
1339 |XX-------    XXXXXXXX    XX----------       XXXXXXX|
1340 |-------X--- -   XXXXX   -XX----------     XXXXXXXX |
1341 |------XXXX----         -XXXXXX-XXX--XX-XXXXXXXXXXXX|
1342 |-X---XXXXXXX--        XXXXXXXXXXXXXXXXXXXXXXXX-XXXX|
      |    |    |    |    |    |    |    |    |    |    |
   700| 705| 710| 715| 720| 725| 730| 735| 740| 745| 750|
```

Legend: Low brightness (blank)
Medium brightness —
High brightness X

Figure 6

UNIFORMITY MAP (UMAP) OF A PART
OF THE SUSQUEHANNA RIVER

```
   754| 759| 764| 769| 774| 779| 784| 789| 794| 799| 804|
      |    |    |    |    |    |    |    |    |    |    |
1271 |-  * **UUUUUU  - * U  *UUUUUUUUUUU** ---U- -  UU  |
1272 |  UUU ** UU-U  *  *  -*UUU UUUUUU **   UUUUU      |
1273 |   UUU *** UU     *    UUU  * UUUUU ***-UU U    U |
1274 |U   - -- *** U **  -  UUU--   UUUUUUU *  * UU-  - |
1275 | U   -  --    -      UUUU   --UUUUUUUU *      - - |
1276 |  U  *-UU     ***   U--UUUU-UU  UUUUUUU-**    UUU U|
1277 |  UU-   -U-     ** - UU-UUU   UUU  *UUU **    -UU  |
1278 |     --  U-    U ** UUUUUUUUUUUUU-  ** UU **   U U |
1279 |          **-       ***UUUUUUUUUUUUU ***** U ***   |
1280 | U-- --        U-- ** UUUUUUUUUUUUUU *** UUU **  UU|
1281 |-          U   -U-- * UUUUUUUUUUUUUUU  ** UUU *** U|
1282 |  *******   - -       * UUUUU-UUUUUUUUUU-  UUUU-** |
1283 |** *****        --  -  * UUUUUUUUUUUUUUUUUUUUUUUU** |
1284 |*       ** *     UU    * UUUUUUUUUUUUUUUUUUUUUUUU**|
1285 |   U      *** * *** -   ** UUUUUUU-UUUUUUU-UUUUUUUU |
1286 | *U-      --* * *** -U  **UU-UUUUUUUUUUUUUUUUUUUUUU|
1287 |    *   --       U--    **UUUU-UUUU UUUUUUUU- UUUUU|
1288 |*   **    -    ** * UU   *  U    -   *--UUUUUUU--U  U|
1289 |*-   -    -UU-- *** ****     *       * UUUUUUUUUU-  |
1290 | UU        --U **   **  **      * - **  UUUU  *    |
1291 |*  - U--UU     U  ***   **  * --  * -      *UU ** *|
1292 | *--      UU--  -        **      - * UUUUUU -  U  -- |
1293 |  *  -   -U- - U       U *    *   * U--UUU   -U **  |
1294 |  -UU-    ---  U      U---    *    *** -UUUUU-   -  * -|
1295 |   -U-UU-  --U        * *      -   - *** UUUUU    UUU--|
1296 | - UUUUUU-  U *  -                ** * UUUUU     UU- |
1297 |   * UUU --    -  *  -              - **** -UUU    -  |
1298 |U-*   UUU        -  U--- U   UU-       -- * -UUUUU U-U|
1299 |         -  UU--  U-      -- - U      - -   * UU- -- U|
1300 |-UU                 U-    -U    -     - U        -  -UU|
1301 |UUUU  -     ---      -      -  -              - *  UUUUU|
     |    |    |    |    |    |    |    |    |    |    |
  754| 759| 764| 769| 774| 779| 784| 789| 794| 799| 804|
```

Legend: High local uniformity u
Medium local uniformity —
Medium local contrast (blank)
High local contrast *

Figure 7

STATISTICS FOR
THE RIVER WATER TRAINING AREA (from STATS)

MEANS AND STANDARD DEVIATIONS FOR GIVEN CHANNELS

18.78	10.70	6.56	1.00
0.86	0.66	0.96	0.51

VARIANCE-COVARIANCE MATRIX

0.74			
0.03	0.44		
0.03	-0.00	0.93	
0.0	0.0	0.06	0.26

CORRELATION MATRIX FOR GIVEN CHANNELS

1.00			
0.05	1.00		
0.04	-0.00	1.00	
0.0	0.0	0.11	1.00

Figure 8

HISTOGRAM FOR THE RIVER WATER TRAINING AREA (from STATS)

```
            HISTOGRAM FOR CHANNEL  1       0.50 - 0.60  MICRONS
            ----------------------------------------------------

17 |***
18 |******************
19 |*********************
20 |************

            HISTOGRAM FOR CHANNEL  2       0.60 - 0.70  MICRONS
            ----------------------------------------------------

10 |*********************
11 |*****************************
12 |***
13 |*

            HISTOGRAM FOR CHANNEL  3       0.70 - 0.80  MICRONS
            ----------------------------------------------------

 5 |*********
 6 |**************
 7 |************************
 8 |******
 9 |*

            HISTOGRAM FOR CHANNEL  4       0.80 - 1.10  MICRONS
            ----------------------------------------------------

 0 |*******
 1 |***************************************
 2 |*******
```

Figure 9

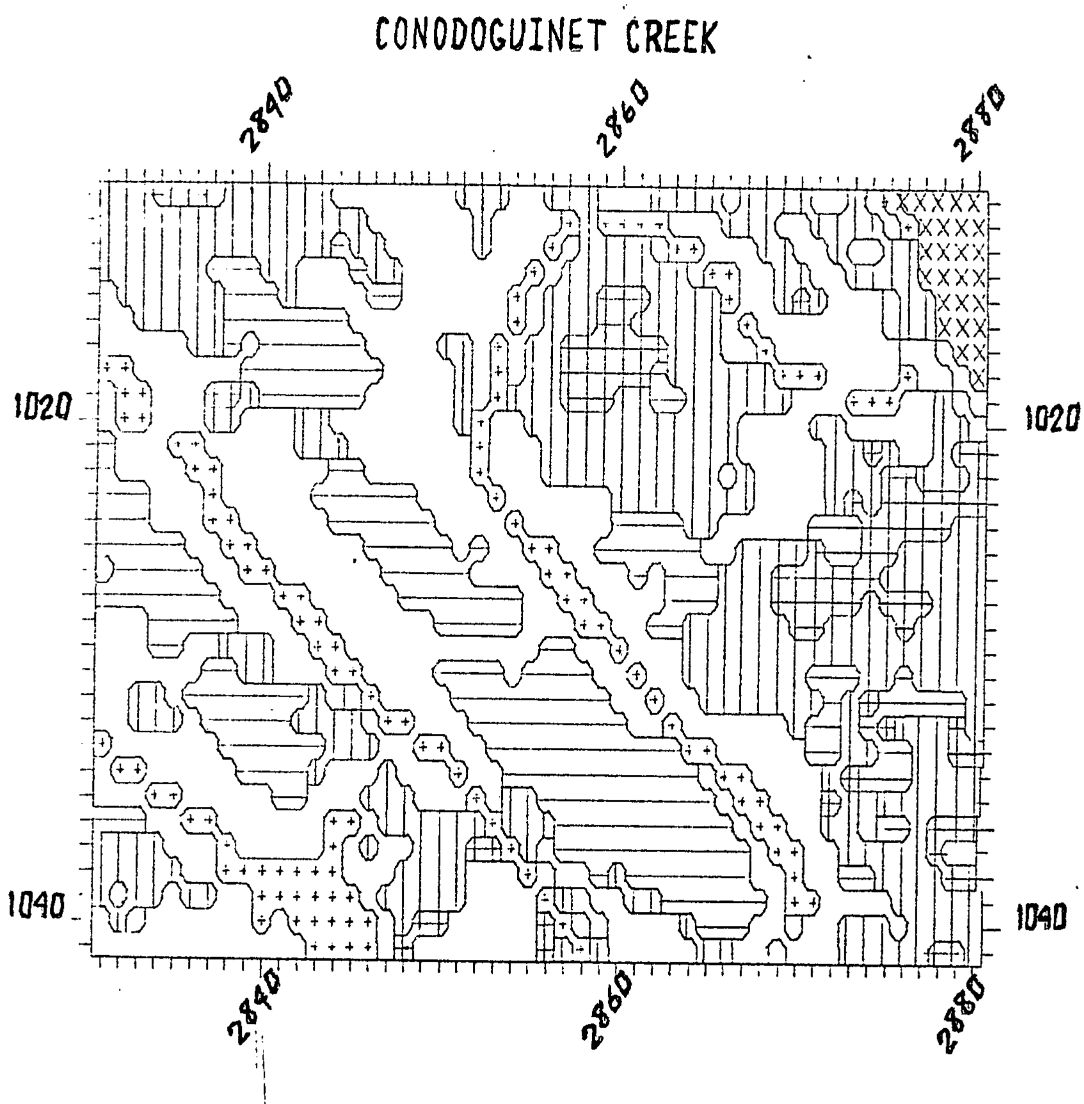
CLASSIFICATION MAP OF THE CONODOGUINET CREEK AREA (DCLASS)

```
  2830|2835|2840|2845|2850|2855|2860|2865|2870|2875|2880|
      |    |    |    |    |    |    |    |    |    |    |
1010 |====---#######------########----###*--####---WWWWWW|
1011 |####=-=-######-------###--###---####*####++#-CWWWWW|
1012 |################------#----C#CCCC---###--####-CWWWW|
1013 |##############=##-----#---C-####-CC---##--#++##WWWW|
1014 |#######===##---=##-------C-#######-CC--##--####WWWW|
1015 |--######===#-----==-----C-###@@@####C--#@#---+##WWW|
1016 |---#####=======---------C-###@@#####-C-------+##WWW|
1017 |C-----##=-======----##-C-##@@@@@@###--C-------**.WW|
1018 |-CC------=========---#-C-##@@@@@=######CCC----C**.W|
1019 |--CC---@@#======-----#-C###@@@##==######---CCC--#-.|
1020 |--CC---##---##-------#C--############----##-----##-|
1021 |==---CC-----###-------C--############-----##@#--#@@|
1022 |==----CC-------==------C--##########-#----###@@###@|
1023 |====---C-----======----C------########----#@#@@@@@@|
1024 |====---CC-----======----C-----====##-----===@@@@@##|
1025 |======--CC------=====-=--CC--======--####@==@@#####|
1026 |--=====--CC------=====----CC---=-===###@@@@@@######|
1027 |=========--CC----========--CC----===###@@@@@#@@@###|
1028 |----=====---CC------=====---CC--==######@@####@####|
1029 |----==--###--CC------------==-C---#################|
1030 |-------==##---CC----====-====--C--######===##=####|
1031 |---##-=======#-*C---==========--C--#######=#@=====#|
1032 |C--###-=====####-CC---==========-C------#==#=@###@#|
1033 |-C------======###--CC--===========CC-----==##==##@@|
1034 |--CC-----====#---#---C--===========-CC----#@===####|
1035 |#---CC-----==---###---C-##==========-CC---@# ######|
1036 |#===--CC------CC-######C##===========-CC--## ==#@@@|
1037 |#####---C-----C-#--###@@C#-============CC--#####@  |
1038 |######--CCCCCCC---####   C --=#=======--C--==####@@|
1039 |## ##-##--CCCCCC-#####    C#*--##======-CC----#####|
1040 |#-# ------C-CCCCC-#@@     @C-*----#===--*--###-####|
1041 |-------------CCCC-@       @#C#-----##--*---#####@@#|
      |    |    |    |    |    |    |    |    |    |    |
  2830|2835|2840|2845|2850|2855|2860|2865|2870|2875|2880|
```

Legend:	Creek water	C	Vegetation	—
	River water	W	Open land	=
	Paved areas	@	Suburban	#

Figure 10

CLASSIFICATION MAP OF
CONODOGUINET CREEK AREA (LMAP)



Legend: Creek water +
River water X
Suburban areas
Paved areas
Open land
Vegetation (blank)

Figure 11

CONODOGUINET CREEK AREA
(Taken from USGS Quadrangle Map:
Harrisburg West, Pa., 1969)

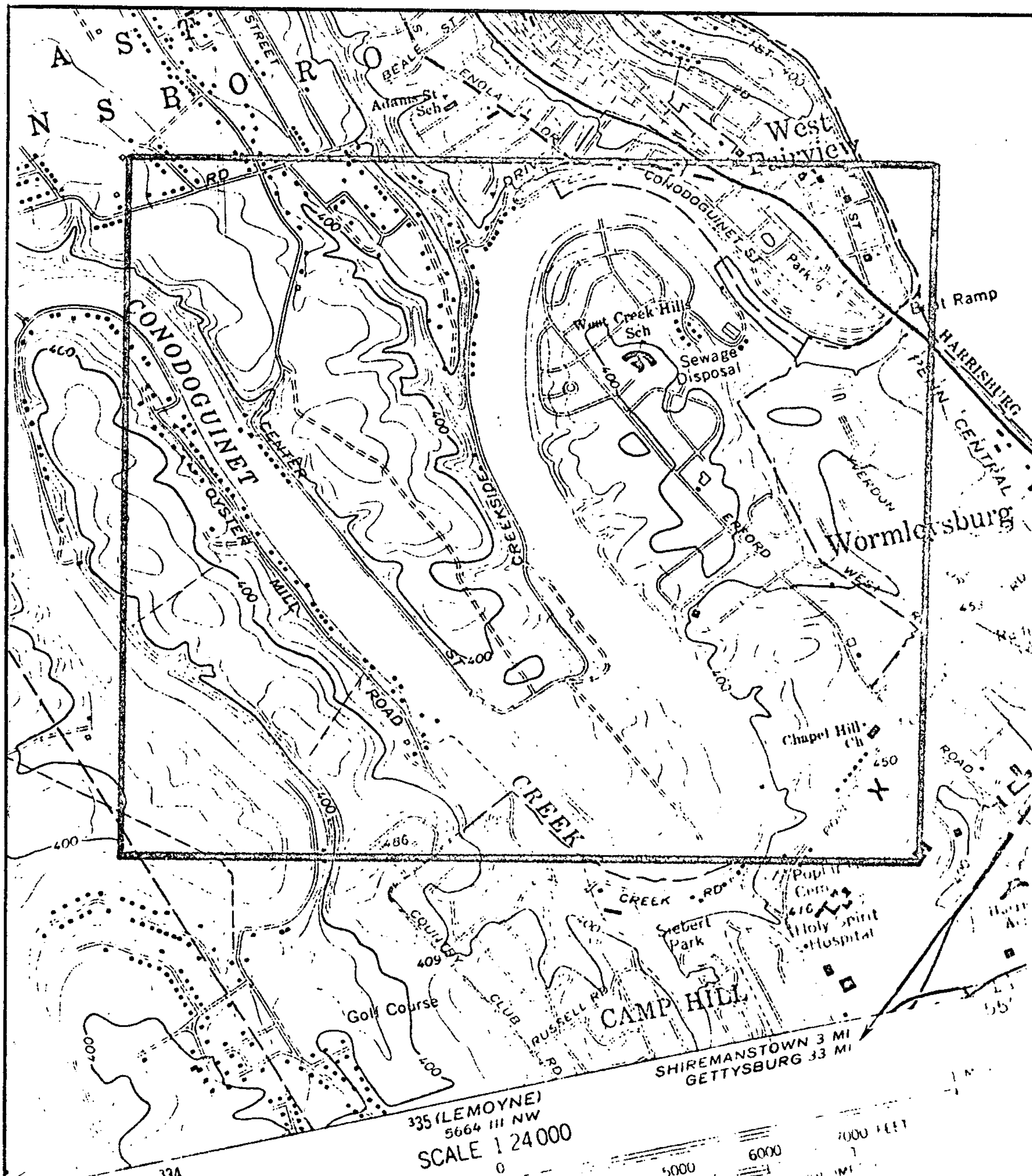


Figure 12

CATEGORY SPECIFICATION FOR
MAPPING CATEGORIES (from DCLASS)

CATEGORY NAME	NUMBER	SYMBOL	LIMIT
FOREST1	1	-	10.0
RAIL1	2	.	10.0
RIVER1	3	W	15.0
GRASS1	4	-	10.0
URBAN1	5	*	10.0
GRASS2	6	-	10.0
FOREST2	7	-	10.0
ROOF	8	*	10.0
SUBURB1	9	#	10.0
HIGHWAY	10	@	10.0
CREEK	11	C	10.0
OPEN LAND	12	=	10.0
BUILDING	13	+	10.0

UN-NORMALIZED CATEGORY SPECIFICATIONS

CHANNELS-		1	2	3	4
1	-	29.28	18.76	46.68	27.60
2	.	37.00	29.45	29.09	10.91
3	W	33.18	22.48	17.76	4.78
4	-	31.78	21.61	41.06	22.00
5	*	36.13	28.25	29.71	12.58
6	-	32.83	22.83	43.79	22.50
7	-	28.25	18.21	49.54	29.82
8	*	52.50	55.00	56.00	22.00
9	#	38.74	31.88	48.01	23.88
10	@	40.59	36.50	51.95	25.59
11	C	33.30	23.52	31.04	13.48
12	=	33.40	22.74	61.00	35.23
13	+	42.42	37.58	39.20	15.90

Figure 13

EUCLIDEAN SEPARATION DISTANCES FOR
MAPPING CATEGORIES (from DCLASS)

DISTANCES OF SEPARATION FOR CATEGORIES

		1 -	2 .	3 W	4 -	5 *	6 -	7 -	8 *	9 #	10 @	11 C	12 =	13 +
1	-	0.0	27.6	37.2	8.8	25.5	8.0	3.8	44.4	16.7	21.8	22.0	17.2	26.8
2	.	27.6	0.0	15.1	18.8	2.3	20.3	31.3	41.7	23.1	28.3	7.7	40.8	14.9
3	W	37.2	15.1	0.0	29.0	15.7	31.5	41.0	56.5	37.4	43.1	15.9	52.9	29.9
4	-	8.8	18.8	29.0	0.0	16.7	3.2	12.5	42.0	14.3	20.8	13.4	24.0	20.2
5	*	25.5	2.3	15.7	16.7	0.0	18.4	29.2	42.0	22.0	27.4	5.7	39.1	15.1
6	-	8.0	20.3	31.5	3.2	18.4	0.0	11.4	39.6	11.7	18.0	15.6	21.4	19.3
7	-	3.8	31.3	41.0	12.5	29.2	11.4	0.0	45.2	18.3	22.6	25.7	14.4	29.6
8	*	44.4	41.7	56.5	42.0	42.0	39.6	45.2	0.0	28.1	22.7	45.3	40.1	26.9
9	#	16.7	23.1	37.4	14.3	22.0	11.7	18.3	28.1	0.0	6.6	22.3	20.2	13.7
10	@	21.8	28.3	43.1	20.8	27.4	18.0	22.6	22.7	6.6	0.0	28.4	20.4	16.2
11	C	22.0	7.7	15.9	13.4	5.7	15.6	25.7	45.3	22.3	28.4	0.0	37.0	18.8
12	=	17.2	40.8	52.9	24.0	39.1	21.4	14.4	40.1	20.2	20.4	37.0	0.0	33.9
13	+	26.8	14.9	29.9	20.2	15.1	19.3	29.6	26.9	13.7	16.2	18.8	33.9	0.0

Figure 14

list of symbols used for showing the various categories. Figure 11 is a line map for the character map of Figure 10. The MSS data for these two maps came from the ERTS-1 pass on August 9, 1972, and the geographical area covered is shown on a part of a USGS quadrangle map in Figure 12. The map of Figure 11 can be seen to have been scaled to coincide with the enclosed area on Figure 12. Figure 13 shows a complete list of symbols used on the map of Figure 11 and also the mean vectors used for each category in computing the Euclidean distances in DCLASS. Figure 14 is a matrix of the distances between vectors for the various categories.

It frequently happens that some targets cannot be specified by uniform training areas, such as streams and similar linear or small scattered features. In such cases, these areas are defined as bounds for analysis by an unsupervised classifier which develops its own set of spectral signatures and statistics using a clustering algorithm. The output of one such program, DCLUS, is shown in Figure 15.

The approach to be employed for change detection or where temporal dimension is involved will be similar to the preceding approach for non-temporal analyses in many respects. The major difference will be in the establishment of permanent training areas for the supervised analysis and classification process and permanent analysis areas for the unsupervised analysis and classification processes. These areas will have to be selected and specified more carefully and with more refinement than when the temporal dimension is not of interest.

2.2.2 HYBRID APPROACH TO ERTS MSS PROCESSING

The results of the ORSER ERTS-I investigation to date have shown that ERTS-I digital data can be translated to map form using only USGS maps for reference, as indicated in the previous section. However, USGS maps alone frequently are insufficient to provide enough information for classification, particularly in areas where rapid tansitions in land use are evident and USGS (or any) maps become obsolete very quickly. Under- flight photography and imagery is considered essential for accurate classification and mapping of ERTS data. In other words, computer techniques alone are not sufficient for thorough analysis of ERTS data.

Photointerpretation techniques have also been applied to the ERTS-I imagery. Of the equipment immediately available to ORSER to date the Saltzman projector appears to give the best overall image definition combined with rapid tracing of observed features. Upon delivery of the Bausch & Lomb Transferscope, ORSER's capability for image interpretation of ERTS will be enhanced considerably. Some preliminary results of work done with the Saltzman projecyor are shown in Table 1.

CLUSTER ANALYSIS MAP (DCLUS) FOR THE

CONODOGUINET CREEK AREA


```
       700| 705| 710| 715| 720| 725| 730| 735| 740| 745| 750|
          |    |    |    |    |    |    |    |    |    |    |
1311 |  +    #-  --  --X- -    --      ++     +   +++    -  |
1312 |    -###--                 #+++  ++++       +++ X     |
1313 |     --* --        X      ##+      ++++  +++ XXX      |
1314 |  +      --X       XX    ++         +++++ X XXX       |
1315 |        -                ++   @@@@  ---*    XXXXXXXX  |
1316 | --          ++++++       +++ #--$----      X +XXXXX  |
1317 |         -   +      ++    +++ #-      -   XXX XXXXX   |
1318 |           ++   +    ++   #++              XXXXXXXXX  |
1319 | -         ++       -+++ -------++              XXXXX |
1320 |  *       +++ ++   ## ++ $$$##++                XXXXX |
1321 |          * ++     @@  +++*-@@@@+*****              XXX|
1322 |    #        ++        ++  -$$#++            -       XX|
1323 |             +++       +++ ----#++           -- X    XX|
1324 |              ++        ++  -----++   XX  -$$--  X    |
1325 |          ----#+     -    ++ ----#++     -$$$---      |
1326 |          ----#++        +++ --   +++    ---  ---  @   |
1327 |+        -$$$$-- +    -   ++ ----#++     --------- --  |
1328 |++   ####$-$$--++       +++ ----  +++        -------  |
1329 |++    ###  ----  ++    -   ++  -----#++++      ---  ---|
1330 | ++    #  $$---#  ++        ++  ------#++++          --|
1331 |X ++         ---##++        +++  -----------+++   $$--|
1332 |XX ++ +     #---$$-++        +++  ------------+++   ---|
1333 |    +++++#-# ----$$#++   -     +++  -----X----#+++X--|
1334 |     ++    ---$$-#$+++          +++  -----------+++-$$|
1335 |      ++   -X-$-&&  --++      -  ++  ---------  ++  -$|
1336 |      ++#   --  #-&&$$ ++          +++  --  X--- +++ --|
1337 | XXX     +++#-     -----++     -     +++  --  -  +++ --|
1338 |        +++            ++          +++++ ++++ #####|
1339 |           +++     ###   ++             ++++++  #####-|
1340 |             +++++##     +++           ++++       ##  |
1341 |         -     +++++++++  XXX            ##           |
1342 |        ----     +++++++ ##  XX       ####   -        |
          |    |    |    |    |    |    |    |    |    |    |
       700| 705| 710| 715| 720| 725| 730| 735| 740| 745| 750|
```

Legend: **Creek** + Unknown @

Urban X **Unclassified** (blank)

Suburban –

Figure 15

Table 1: Results of Photointerpretation of ERTS Imagery Using the Saltzman Projector.

Land Use Category	Channel 4	Channel 5	Channel 6	Channel 7	Preferred Channel
Drainage (Blue)	Incomplete. Islands obscured. Shorelines grade into forest.	Incomplete. Shorelines grade into forest.	Confused with urban.	Some confusion with urban.	Channel 7
Roads (Brown)	Very incomplete.	Clearly defined where white. Unreliable when parallel to scan lines. Many dark lines could be roads or drainage.	Rarely seen and poorly defined.	Rarely seen.	Channel 5
Urban (Black)	Grades into suburban.	Confused with probable bare fields. Otherwise fairly distinct.	Minor confusion with suburban and drainage.	Confused with drainage.	Channels 5 & 6
Suburban (Gray)	Not differentiable from urban. Confused with agriculture.	Not differentiable from agriculture.	Confused with agriculture.	Fair to poor distinction from both agriculture and urban.	All poor, due to confusion with agriculture.
Forest (Dark green)	Not differentiable from drainage and often confused with agriculture.	Some confusion with drainage.	Confused with agriculture.	Confused with agriculture.	Channel 5
Agriculture (Light green)	Confused with forest and often with suburban.	Not differentiable from suburban.	Confused with both forest and suburban.	Confused with forest and with portions of suburban.	All poor, due to confusion with forest and suburban.

It can readily be seen that only in a few cases could a feature be uniquely determined by this technique along. Use of U-2 and C-130 imagery has been found to improve the interpretation results, but in general, photointerpretive techniques have not been completely satisfactory as a single means.

As a not unexpected results of preliminary ERTS-I work, ORSER strongly feels that a hybrid approach is essential. Computer differentiation of areas from scanner data is far superior to that done by the human eye, but the photointerpreter is essential, as an integral part of data processing, for providing identification of features exhibited on computer output.

Figure 16 shows a flow diagram showing the ORSER hybrid approach to processing of ERTS imagery. A brief explanation of the steps in the procedure is given below. The Roman numerals and letters used below correspond directly to the same symbols in Figure 16.

Guide to Flow Diagram of ORSER Hybrid Approach to Interpretation of ERTS Data

I. Preliminary
   - A. Set scan line and element limits and identify cloud locations.
   - B. This becomes the working tape.
   - C. Identify clouds.
   - D. Review for definable boundaries.

II. First Level Mapping
   - A. Photo Interpreter and Computer Mapper collaborate. Select easiest targets first. Choose spectrally homogeneous items with positive geographic locations. Select replications in widely separated areas.
   - B. Identify some targets on U MAP.
   - C. Check for uniformity on U MAP. Attempt to find large number of like elements. Loop A, B, & C.
   - D. Review statistical characteristics of defined targets.
   - E. Make first run on classification map.
   - F. This is a verification step. Project U-2 image onto computer map. Identify satisfactory classificiations. If some areas lack definition, redefine training areas.

ORSER HYBRID APPROACH TO
INTERPRETATION OF ERTS DATA

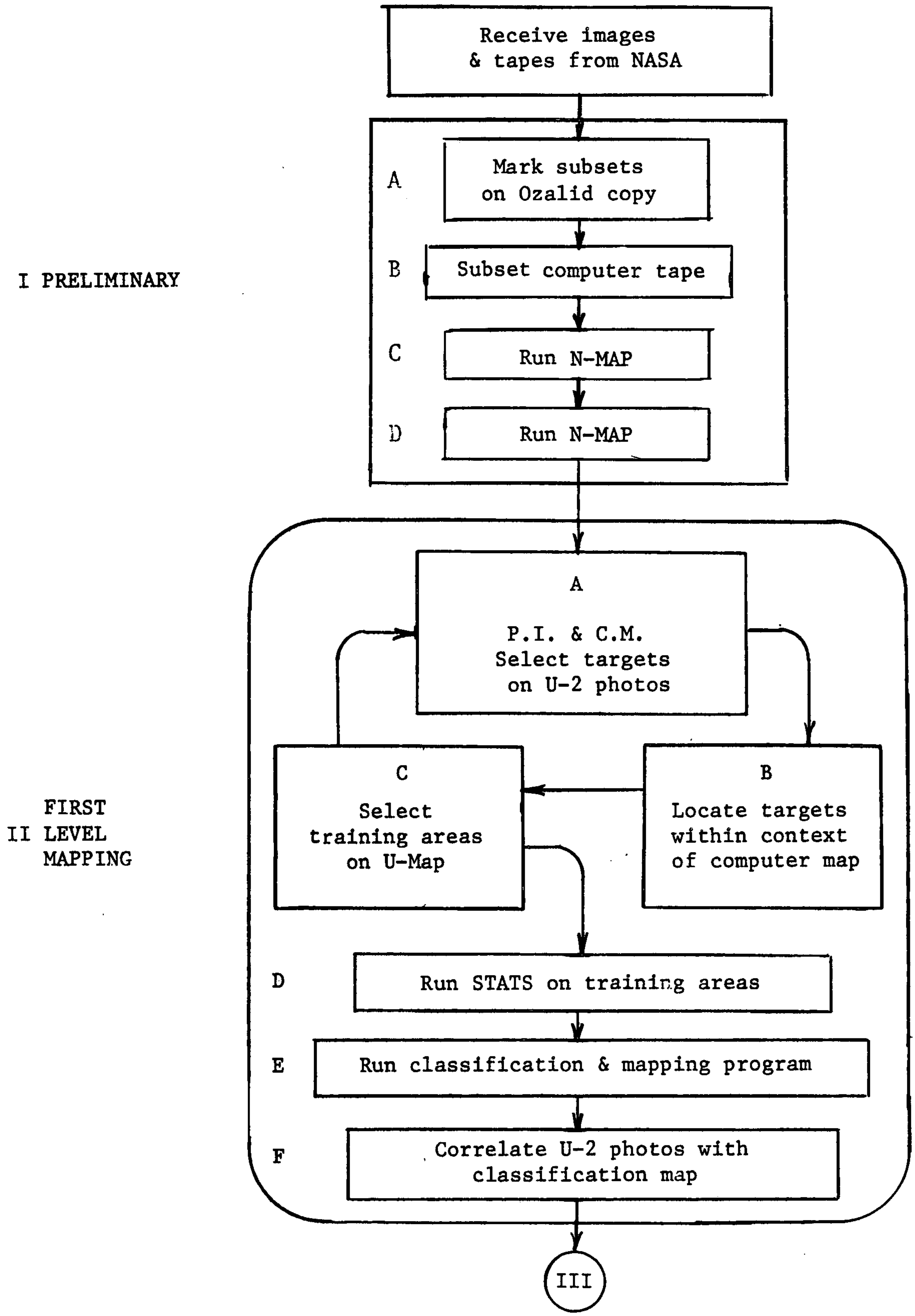


Figure 16 (a)

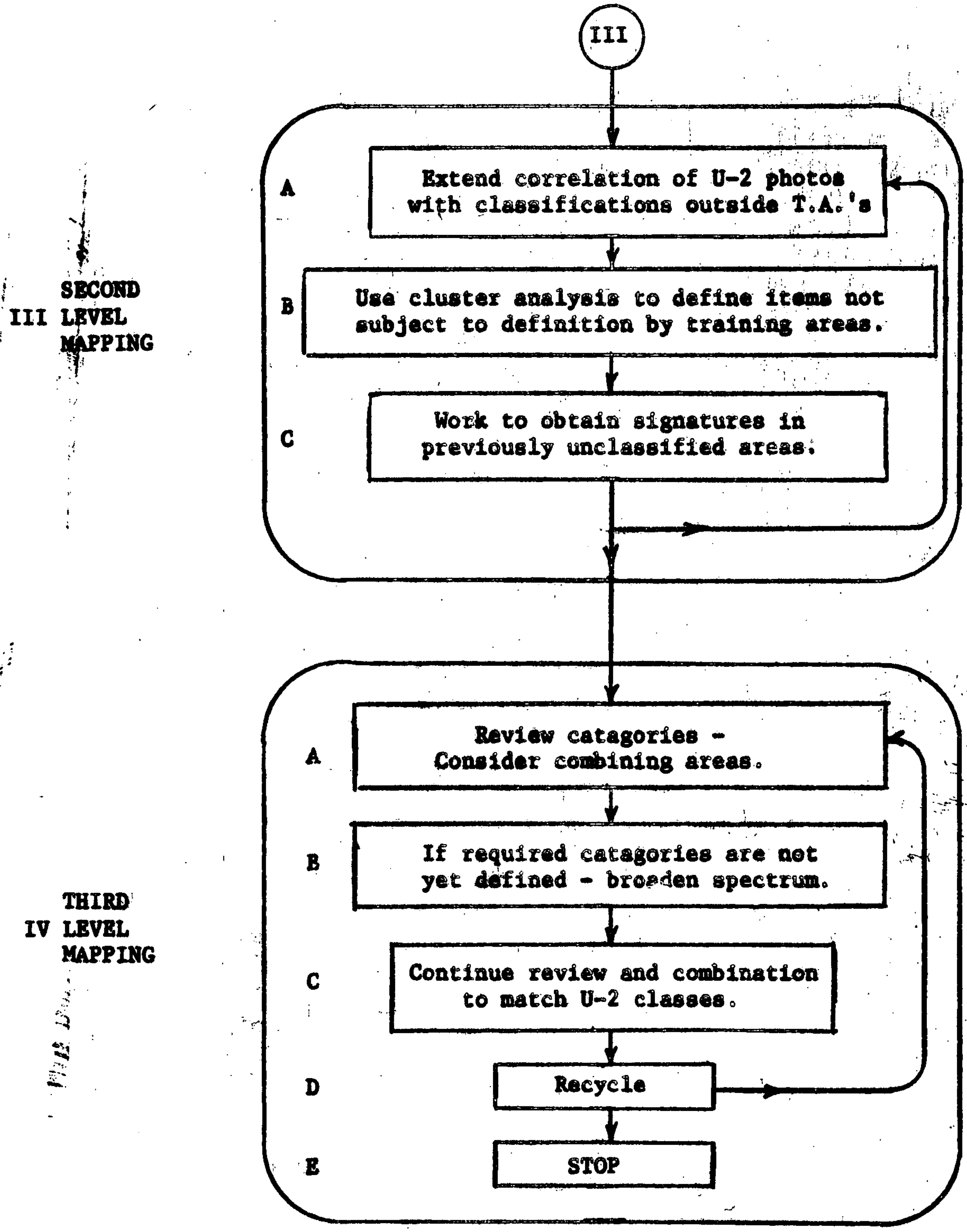

III
SECOND
III LEVEL
MAPPING
A
Extend correlation of U-2 photos with classifications outside T.A.'s
B
Use cluster analysis to define items not subject to definition by training areas.
C
Work to obtain signatures in previously unclassified areas.
THIRD
IV LEVEL
MAPPING
A
Review catagories - Consider combining areas.
B
If required catagories are not yet defined - broaden spectrum.
C
Continue review and combination to match U-2 classes.
D
Recycle
E
STOP

Figure 16 (b)

III. Second Level Mapping

A. Attempt to identify outside traning areas.

B. Using cluster analysis, define items not subject to definition by training areas. These might be linear features or stream channels. Add these to the list of signatures and continue.

C. This is a recycle with smaller training areas and more weight placed on cluster analysis.

IV. Third Level Mapping

A goal is to have successful definition of approximately 75% of the subset area at this point.

A. Now review the classification categories originally defined as desirable. If present map output is unnecessarily refined, lump sum groups.

B. Some categories will require lumped parameters in terms of spectral content. These will require a series of successive approximations at defining the units. Training areas are less spectrally homogeneous.

C. Requires collaboration of Photinterpretor and Computer Mapper.

D. Establish limiting goal.

Ground truth data is, of course, another essential element in the proper interpretation of ERTS data. Ground truth collection will be performed as necessary by the investigators. In addition, The Pennsylvania State University currently possesses a unique collection of ground truth data for Pennsylvania. This will be an invaluable aid in establishing references and interpreting data obtained from ERTS and other sources. The following are some examples of readily available ground truth:

1. 25 of Pennsylvania's counties with published modern soil surveys
2. Soil characterization data on approximately 600 soil profiles
3. Various geologic, physiographic, relief, stream and soil maps of Pennsylvania
4. Various instrumented watersheds, such as the Manhantago watershed, which is one of the most highly instrumented Agricultural Research Service watersheds.
5. Facilities and plots of the Pennsylvania State University Sewage Effluent Project
6. A complete set of orthomapping data from a 130 square mile area in and around State College, Pa. The scale will be one inch to 200 feet.
7. Complete data bank of former and existing meteorlogical data for Pennsylvania including raw data, data or punch cards and magnetic tape, and data on microfilm as well as all <u>Climatological Data</u> publications.